Thermal/Heat Transfer Analysis Using a Graphic Processing Unit (GPU) Enabled Computing Environment

Completed Technology Project (2011 - 2012)

Project Introduction

Simulation technology plays an important role in propulsion test facility design and development by assessing risks, identifying failure modes, and predicting anomalous behavior of critical systems. Integrated analyses of facility designs including supersonic diffusers, steam ejectors, valves, cooling spray nozzles, and turning ducts will be carried out for both steady state operation and shutdown/startup transients. The proposed innovation expands on the multi-element unstructured Computational Fluid Dynamics (CFD) which has been validated for complex valve/feed systems and high pressure propellant delivery systems used in engine and component test stands. The objective is to speed-up analyses time of heat transfer and thermal effects through the utilization of Graphic Processing Unit (GPU) enabled computing. The focus is on porting the thermal solver used in CFD multi-physics simulation framework to GPU architectures, so that GPU computing technology can permit modeling tasks that were restricted to high-end computational facilities to be achieved on local workstations. This will significantly enhance current analysis framework by facilitating analyses of complex heat transfer problems on desktop workstations with rapid turnaround. This capability will be expanded to include advanced models for analysis of non-equilibrium two-phase flow dynamics and heat transfer in water injection systems in the flame deflector, steam loaded plume entrainment, chemical steam generator performance, and operation of steam ejectors.

The objective of this effort was to identify a novel approach to accelerate the time required for computing high-fidelity heat transfer problems using graphics hardware (GPUs). Traditionally, these types of analyses have been carried out on multiple processors or PC clusters that require significant costs for establishing and maintaining the computing environment. This project aggressively investigated the method of using of GPU enabled computing, to expedite analyses time of heat transfer and thermal effects. To accomplish this, the algorithms used were innovatively re-engineered for use on desktop computers with GPU enabled architectures which resulted in a substantial reduction in the cost of carrying out analyses as well as shortened turnaround time. Preliminary studies demonstrated that when using the GPU-ported heat transfer package, runtime acceleration factors exceeded 800%.. Enabling the capability to gain large levels of computational acceleration is significant due to the fact that it permits desktop workstation computing platforms to perform high-fidelity flow modeling of transient heat loads in suitable and usable timeframes. The findings from this study are additionally significant because it demonstrated a cost-efficient and effective path for exploiting an untapped level of parallelism can successfully be used for high fidelity simulation. The transitioning to GPU computing will give NASA personnel an opportunity to assess the potential applicability of these platforms to other software support systems.
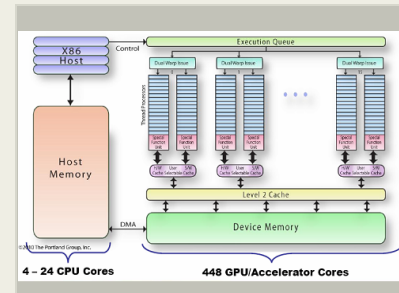
Heat Transfer Using GPU Enabled Computing Environment

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Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Lead Center / Facility:

Stennis Space Center (SSC)

Responsible Program:

Center Innovation Fund: SSC CIF

Anticipated Benefits

The Thermal/Heat Transfer Analysis Using a GPU Enabled Computing Environment will directly benefit NASA funded missions by providing an enhanced analysis capability that will provide a rapid turnaround time to support test facility analysis and preparation. GPU computing has the potential of reducing analysis and modeling time by one to two orders of magnitude compared to current CPU workstations.

Primary U.S. Work Locations and Key Partners
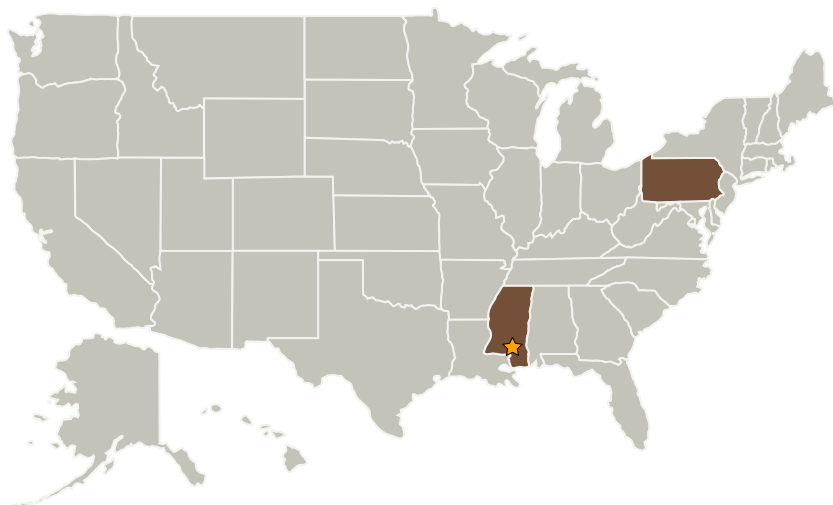
Organizations Performing Work	Role	Type	Location
⭐Stennis Space Center(SSC)	Lead Organization	NASA Center	Stennis Space Center, Mississippi

Primary U.S. Work Locations	
Mississippi	Pennsylvania

Project Management

Program Director:
Michael R Lapointe

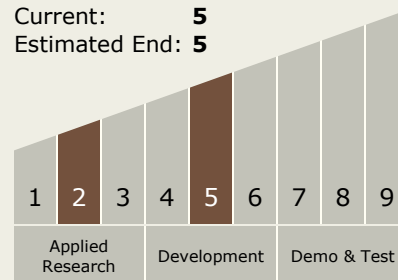**Program Manager:**
Ramona E Travis

Project Manager:
Daniel C Allgood

Principal Investigator:
Daniel C Allgood

Technology Maturity (TRL)

Start: **2**
Current: **5**
Estimated End: **5**

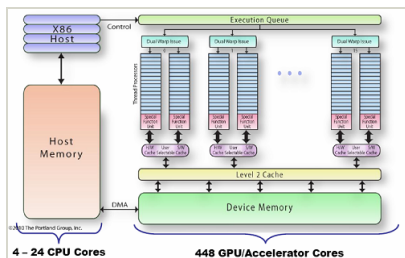| 1	2	3	4	5	6	7	8	9
Applied Research			Development			Demo & Test		

Technology Areas

Primary:

- TX13 Ground, Test, and Surface Systems
  └ TX13.1 Infrastructure Optimization
    └ TX13.1.6 Test, Operations, and Systems Safety

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